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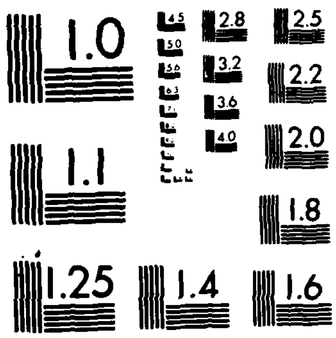

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AD-A140 646

SAR
MEASURES OF EFFECTIVENESS
FOR
ADVANCED MARINE VEHICLES

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DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

October 1983
FINAL REPORT

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16. Abstract

This report describes analytical work that was performed to compute measures of effectiveness (MOEs) of advanced marine vehicles (AMVs) in performing search and rescue (SAR) missions. The report also discusses *difficulties* that were encountered in analyzing the SAR data base.

The objective of this study is to search the 1981 SAR data base for information that is pertinent to an analysis of an AMV in performing SAR missions. Correlations are identified between the probability of saving lives and other factors in the SAR data base, especially environmental factors and time delays. These correlations are used to quantify the potential contribution of the AMV to overall SAR performance under a range of environmental conditions.

Survival curves generated from the 1981 SAR data base show that in approximately one third of the SAR cases, the probability of survival very definitely degrades with time. Consequently, a high-speed AMV could provide an increase in the probability of saving lives in cases where distance to scene is substantial. The relatively shallow slope of the curve suggests, however, that moderate speed advantages or speed advantages over short distances (especially if get-away time is increased for the AMV) will have little or no effect on SAR mission effectiveness.

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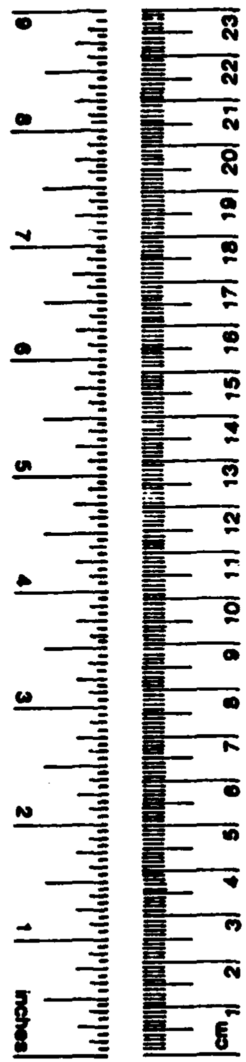
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

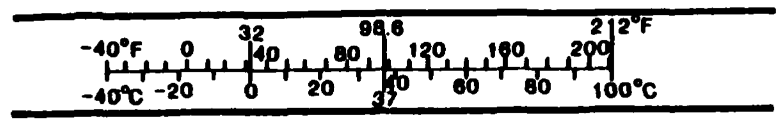
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10.286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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FOREWORD

The Advanced Marine Vehicle (AMV) program is administered by the Office of Research and Development (G-DMT-2) in Coast Guard Headquarters. One of the objectives of the AMV program is to assess the operational performance of various advanced concepts such as hydrofoils and surface-effect ships. This report describes an analytical approach that was developed to compute measures of effectiveness (MOEs) that can be used to evaluate the performance of an advanced marine vehicle as well as conventional ships in a search and rescue role.

The analysis described in this report is the result of a joint effort between personnel from the Coast Guard Research and Development Center in Groton, Connecticut, and Analysis & Technology, Inc., in North Stonington, Connecticut. Under this contract (DTCG39-82-C-80349), preliminary measures of effectiveness were previously developed.

The personnel who have been associated to various degrees with this phase of the project are:

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SECTION I

INTRODUCTION

1.1 PURPOSE

The purpose of this report is to describe analytical work that was performed to compute measures of effectiveness (MOEs) of advanced marine vehicles (AMVs) in performing search and rescue (SAR) missions. The report also discusses difficulties that were encountered in analyzing the SAR data base.

1.2 BACKGROUND

The advanced marine vehicle program consists of technical and operational evaluations (TECHEVAL/OPEVAL) and operations research and operations analysis (OR/OA). The TECHEVAL/OPEVAL is concerned primarily with the engineering and operational characteristics of AMVs. This information is obtained through test and evaluation of existing vessels, ship model tests, and analytic and engineering studies. Much of this information will make up the AMV data base in the Office of R&D.

The OR/OA portion of the AMV project is structured to answer questions relating to operational performance and ownership of AMVs. Items such as life-cycle cost, the required number of vessels, maintenance, reliability, mission performance, and the ranking of overall performance for different vessels within the expected mix of missions are included in the OR/OA portion of the project. This report addresses mission performance in SAR. The MOE traditionally used by the Coast Guard (G-OSR-3) to measure performance in SAR missions is the number of lives saved following a call for assistance. The probability of saving lives can be computed as a function of many variables, e.g., district, distance from shore, water temperature, etc. A large amount of data on SAR missions, including time, date, location, and severity of the incident, is stored in the Coast Guard SAR data base, which dates back to 1973. The SAR data base provided all the data used in this analysis. (Value of property saved is also used as a SAR MOE, but it is not addressed in the analysis. The value of lives saved is far more important than the value of property saved. Generally, if the Coast Guard can arrive in adequate time to save lives, it can also save property.)

1.3 SEARCH AND RESCUE PATROL DESCRIPTION/OVERVIEW

In order to estimate the potential contribution of the AMV in a SAR mission, it is necessary to understand how SAR operations are conducted. Search and rescue is generally a responsive mission. Once notified, the Coast Guard dispatches boats, cutters, and/or aircraft to search for and rescue people and property. Craft may be dispatched from port or diverted while on another mission. Sometimes a single resource is used on a SAR mission, but a number of resources and a number of sorties by an individual resource may be used if circumstances demand. The type of resource dispatched is determined by distance to scene, weather, nature of the problem, and availability.

Reports of each SAR case are collected from every unit that participates in a particular case, and an individual record is included in the SAR data base for every sortie by a unit. The entire SAR data base is available on tape for statistical analysis.

1.4 OBJECTIVE

The objective of this study is to refine the SAR MOE by searching the 1981 SAR data base for information that is pertinent to an analysis of an AMV in performing SAR missions. Correlations are identified between the probability of saving lives and other factors in the SAR data base, especially environmental factors and time delays. These correlations are used to quantify the potential contribution of the AMV to overall SAR performance under a range of environmental conditions.

SECTION 2

TECHNICAL APPROACH

2.1 ANALYSIS OVERVIEW

The analysis procedure developed to evaluate the performance of advanced marine vehicles (AMVs) in conducting SAR missions is presented in figure 2-1.

Initial analysis of the SAR data base indicates that many cases are not pertinent to AMV analysis. Non-emergency cases that occur in mild weather within sight of shore shed no light on the performance of a high-speed AMV. Moreover, including tens of thousands of non-emergency cases overwhelms the statistics and buries the sensitivity of SAR performance to almost any factor. Consequently it is necessary to reduce the SAR data base to an appropriate subset of relevant cases.

Data in the SAR data base need to be converted for statistical analysis. All times are converted to elapsed time from Coast Guard notification. Since water temperature is assumed to be a factor in survival, it is added to the SAR records. Mean water temperature curves from reference(a)are used to determine water temperature for each case as a function of month of the year and latitude/longitude coordinates.

The MINITAB statistical analysis package developed at Pennsylvania State University is used on a VAX 11/780 computer to generate statistical reports. These reports are studied for trends that might be useful in evaluating the AMV in a SAR role.

It is hypothesized that survival curves can be generated for a range of environmental conditions. It is known from the hypothermia curves and other data that the probability of a person's surviving after a boating accident not only degrades with time, but degrades faster in cold water. It will be possible to generate a curve in which the probability of survival and a confidence interval on the probability is plotted versus time. Figure 2-2 depicts such a theoretical survival curve. Since time can be converted to distance from station as a function of ship speed in the seaway, such a curve would be valuable in evaluating AMV performance. Knowing the distribution of case distances from station, it should be possible to determine a representative MOE by integrating to the probability of saving lives as a function of craft speed in the seaway.

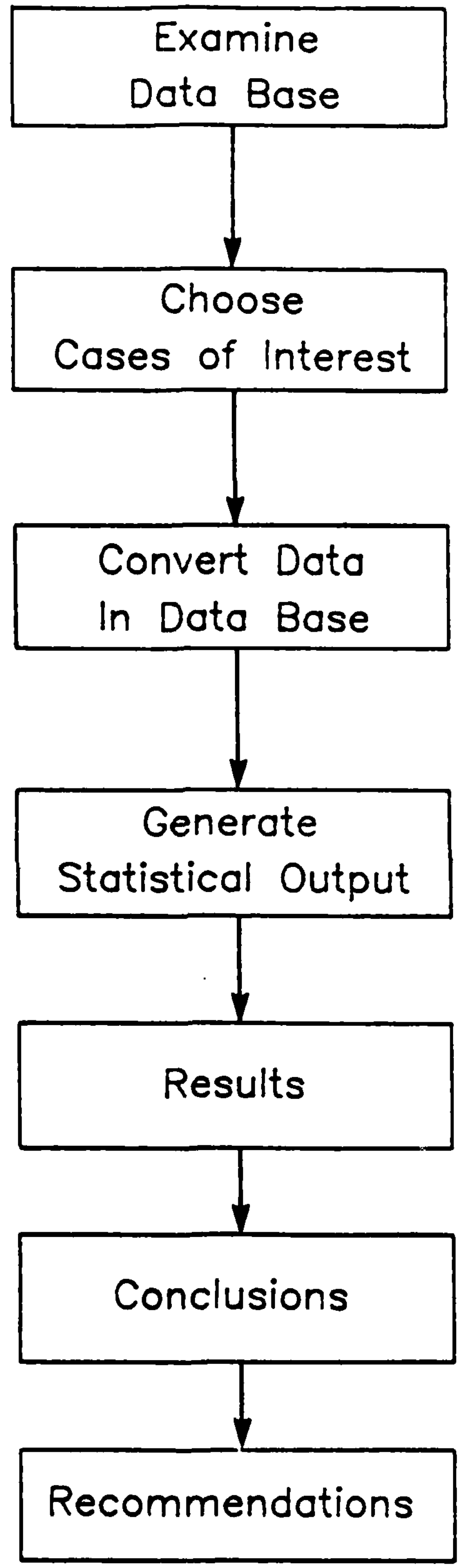
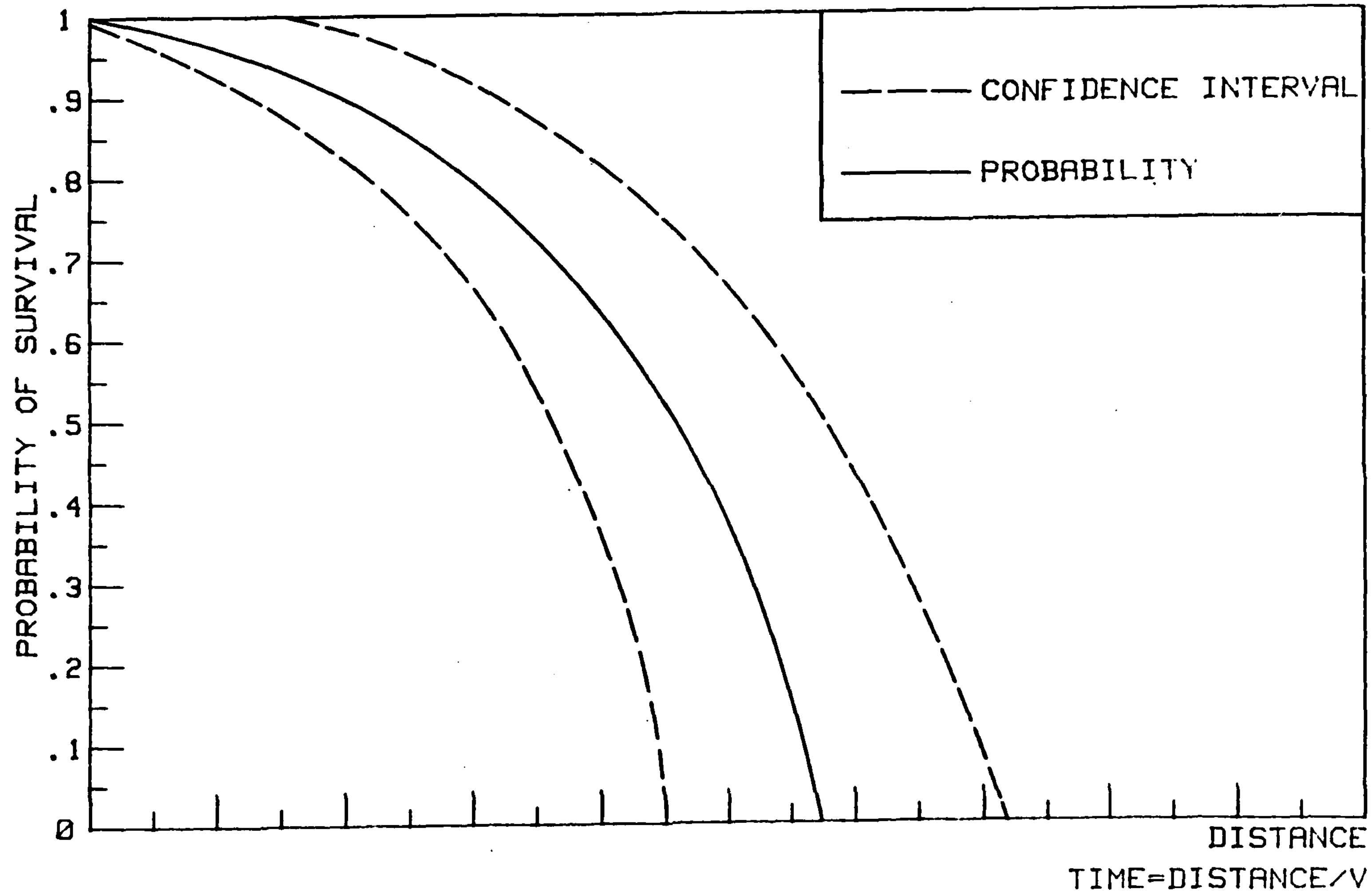


Figure 2-1. SAR Analysis Procedure



NOTE: V = VESSEL SPEED IN THE SEAWAY (KNOTS)
DISTANCE = DISTANCE TO SCENE (NAUTICAL MILES)

Figure 2-2. Theoretical Survival Curve for a Given Set of Environmental Conditions

2.2 STATISTICAL ANALYSIS OF THE SAR DATA BASE

2.2.1 Case Selection

The 1981 SAR data base contains information on 93,000 sorties. Of the 1,717 lives lost, 637 of these occurred before the Coast Guard was notified. In these cases of life lost before notification, type of rescue craft is irrelevant. Also, many lives were lost in inland waterways or on land where the AMV speed in the seaway is irrelevant.

Since it is desired to study the AMV in a rescue role over a range of environmental conditions, cases selected for analysis include all severe cases that occurred only off the coast of the continental United States (including Alaska) during the winter months (January, February, and March) and the summer months (July, August, and September). Severe is defined as a case in which either a life was lost or a life that would have been lost was saved (life saved is determined by the Coast Guard and is so indicated in the data base). This selection reduced the 1981 SAR data base to a subset that includes 776 cases and 2,392 rescue sorties. A total of 225 lives were lost after the Coast Guard was notified, 113 were lost before the Coast Guard was notified, and 1,501 lives were saved (see figure 2-16).

2.2.2 Time of Incident

Defining the probability of survival as a function of time requires identifying the beginning of the incident. Life-threatening situations at sea often evolve over time: the weather gets rough, the boat starts taking on water, the pumps break down, people enter life boats, and/or eventually people may get wet or enter the water. At some time in this evolution, the Coast Guard is notified. Injuries that affect a person's chances of survival can occur during this process. The difficulty of identifying time of incident is evident from analysis of the entry in the SAR record, "Time from incident to notification." This is almost universally a "0", "9" or "99" indicating "no time", "more than 9 hours" or "unknown." An accident can actually become life threatening after the Coast Guard is notified if, for instance, bilge pumps fail and the vessel sinks while help is on route. Because of the virtual impossibility of identifying the time at which a life becomes in danger, time of notification is used as a baseline in the analysis on the assumption that time from incident to notification adds a finite average amount of time to the survival curve.

Two additional problems arise in regard to time of incident. In the cases of injury during boating accidents, one life could be in jeopardy many hours before another. The SAR data base cannot reflect this difference. Also, it is very likely that the SAR record contains data on the time the boat came into jeopardy, e.g., mast broke, ran out of fuel, lost direction, rather than the time peoples' lives came into jeopardy.

Although identifying time of incident from the SAR data base is a problem, two other problems complicate the analysis. Often it is not known how long a person remained alive before dying. If the body is not found or if no information is available on when a person died, it is impossible to identify the length of time a person remained alive.

2.2.3 SAR Data Deficiencies

A number of deficiencies in the SAR data base have been identified during this analysis effort. Because the intent of the analysis is to generate survival curves as a function of environmental parameters, it is necessary to know the environmental parameters. An examination of a number of multi-unit cases shows a wide range of values for wind speed, visibility, and sea state for the various sorties on a multi-unit case (see figure 2-3).

Environmental conditions do change with location and time. The data on the multi-unit cases, however, cast doubt on the accuracy of environmental information describing the location of the accident during the time people were in water, especially in the cases in which a person died and was not located.

The accuracy of data in the SAR data base is of great concern when the SAR data base is used for statistical analysis. In numerous cases, elapsed times from notification are negative. Also, if a date/time group states erroneously that a unit was underway on the 10th of the month when the Coast Guard was notified on the 11th, the elapsed time becomes 30 days since an algorithm assumes that the 10th is in the next month. These negative times and very large times must be edited or they can make statistical analysis meaningless.

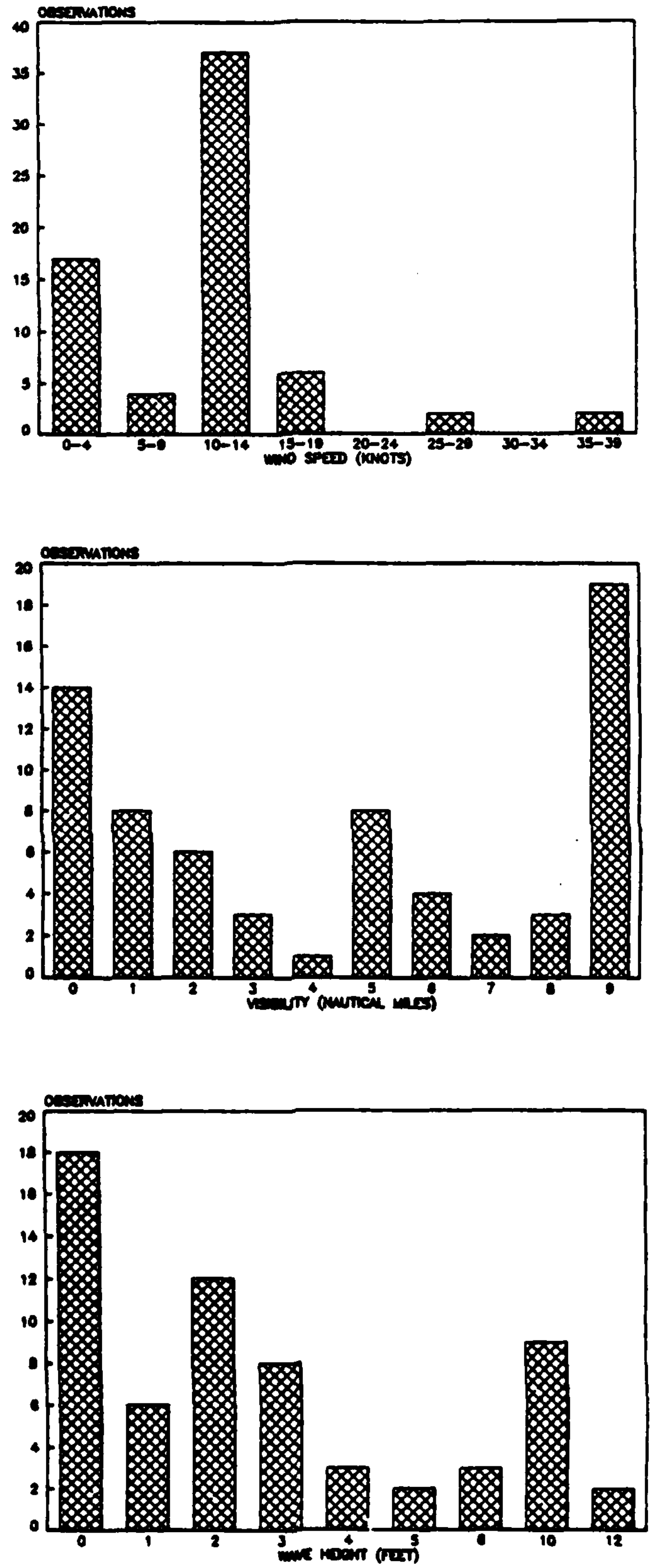


Figure 2-3. Multi-Unit Case No. 8104 Environmental Data (125 Sorties over 10 days)

Another concern with the data is the suspicion that "safe" responses are sometimes used. Mission performance is an example of this problem. Mission performance is divided into three categories: resource, personnel factor, and logistics. The coding responses for these three factors are almost universally:

00 Resource and equipment performed properly
20 Personnel adequate
30 No logistic problems

The few cases in which other codes are used form too small a sample for statistical significance. Moreover, one is hesitant to make a statement on mission performance based on the occasional case in which mission performance is listed as less than perfect. Although this data may be accurate, there is a skepticism that systems and people always perform satisfactorily at sea.

2.3 ANALYSIS

2.3.1 Distance From Shore Greater than Three Nautical Miles

The initial approach to AMV evaluation was to study cases that occurred beyond three nautical miles from shore. It was postulated that a high-speed craft would be most effective if the case occurred in the open ocean, in poor weather. Analysis of the 1981 data base indicates that relatively few SAR deaths occur in the open ocean (108 in 1981). Loss of life in the open ocean occurred under a wide range of environmental conditions, but generally favorable weather [see figures 2-4 (a and b)]. The small number of deaths beyond three nautical miles is inadequate for generating survival curves as a function of environmental conditions. Moreover, the data available show a very consistent probability of survival over the range of environmental conditions, which was not expected. In figure 2-4(a), note the probability of survival decreasing with waves over 16 feet

2.3.2 All Ocean Cases

Even though the vast majority of cases and deaths occur within three nautical miles of shore, the distance to scene is often considerable since craft often are dispatched from ports or positions many miles away. Figure 2-5 depicts the distribution of distances to scene for all the cases selected for analysis.

a. Visibility (nmi)

Observed Sea (feet)	0		1		2		3		4		5		6		7		8		9		All Visibility	
	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#
0	.87	63	1	3	0	0	0	0	0	0	1	6	1	2	1	7	1	8	.92	59	.91	148
1	1	1	1	7	.83	6	1	2	1	4	1	3	1	1	0	4	.96	27	.88	25	.89	80
2	*.75	4	0	1	.50	2	1	1	0	1	1	7	.40	5	.98	57	.67	6	.96	46	.91	130
3	1	7	1	3	0	0	1	3	0	0	.50	4	.86	7	1	3	1	6	.80	51	.85	84
4	1	15	1	11	1	2	0	0	0	1	.73	15	1	9	1	5	0	1	.90	29	.90	88
5	0	0	0	0	0	0	.50	2	1	7	1	2	1	8	1	10	.85	13	.92	25	.93	67
6	1	1	1	2	0	0	1	5	1	3	.67	9	1	4	0	3	1	50	.86	21	.91	98
8	1	7	0	0	1	4	0	0	1	15	1	6	1	2	0	0	1	29	.86	14	.97	77
11	1	36	1	17	.50	2	1	6	1	1	.67	3	0	0	1	2	0	4	.78	9	.90	80
16	1	2	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	1	6	1	11
23	0	0	0	0	1	1	0	0	0	0	.40	40	0	0	1	4	0	0	0	4	.43	49
All Sea	.93	136	.98	44	.85	20	.95	19	.94	32	.64	95	.89	38	.92	.95	.93	144	.88	289	.88	912

Note:

p = Probability of Survival

= Number of lives lost and lives saved

* = Example: .75 x 4 = 3 lives saved

Figure 2-4. Cases More than Three Nautical Miles from Shore (Environmental Data)

b. Wind (knots)

Observed Sea (feet)	1		5		7		10		15		25		35		50		All Wind	
	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#
0	.90	79	.96	28	1	20	.67	12	1	7	1	1	1	1	0	0	.91	148
1	.88	8	.81	21	.43	7	1	17	1	27	0	0	0	0	0	0	.89	80
2	1	8	*.80	10	.88	16	.92	24	.67	18	1	54	0	0	0	0	.91	130
3	1	2	.67	9	1	3	.89	27	.77	31	1	11	1	1	0	0	.85	84
4	0	0	1	3	.67	3	.81	16	.92	50	.94	16	0	0	0	0	.90	88
5	1	3	0	0	1	2	.91	23	.88	26	1	7	1	6	0	0	.93	67
6	1	4	1	4	0	0	.91	43	.87	15	.97	29	1	1	0	2	.91	98
8	1	4	1	7	0	0	1	2	.93	28	1	34	1	2	0	0	.97	77
11	0	0	0	1	0	0	.86	7	.50	2	.83	23	.98	40	1	7	.90	.80
16	0	0	0	0	0	0	0	0	0	0	1	2	1	3	1	6	1	11
23	.31	35	0	0	0	0	0	0	1	4	1	5	0	4	1	1	.43	49
All Sea	.77	143	.87	83	.86	51	.89	171	.88	208	.97	182	.91	58	.88	16	.88	912

Note:

p = Probability of Survival

= Number of lives lost and lives saved

* = Example: .80 x 10 = 8 lives saved

Figure 2-4. Cases More than Three Nautical Miles from Shore (Environmental Data) (continued)

DISTANCE TO SCENE (2392 SORTIES)
EACH * REPRESENTS 15 OBSERVATIONS

MIDDLE OF INTERVAL (NMI)	NUMBER OF OBSERVATIONS (SORTIES)	
1.00	463	*************************** ****
3.00	148	**********
5.00	123	*********
7.00	85	******
9.00	81	******
11.00	121	*********
13.00	58	****
15.00	85	******
17.00	22	**
19.00	30	**
21.00	85	******
23.00	18	**
25.00	71	*****
27.00	12	*
29.00	9	*
31.00	60	****
33.00	13	*
35.00	31	***
37.00	10	*
39.00	5	*
41.00	50	****
43.00	5	*
45.00	18	**
47.00	2	*
49.00	7	*
51.00	44	***
53.00	5	*
55.00	25	**
57.00	3	*
59.00	3	*
61.00	52	****
63.00	4	*
65.00	16	**
67.00	5	*
69.00	2	*
71.00	16	**
73.00	2	*
75.00	12	*
77.00	3	*
79.00	4	*
81.00	18	**
83.00	1	*
85.00	13	*
87.00	2	*
89.00	1	*
91.00	34	***
93.00	1	*
95.00	8	*
97.00	3	*
99.00	503	**********************************

Figure 2-5. Distance to Scene Distribution

Distance to scene is a somewhat difficult statistic for analytical purposes since it is defined as the distance the unit travelled from its location at time of notification. Craft can be in the area of the case or can be dispatched from distant ports and stations. The distance craft travelled on previous cases (especially aircraft) may not be relevant to the distances that an AMV would have to travel from port.

Time to scene would be a more useful statistic for analysis, but "Date/time assisted unit located" is set to zero if the assisted unit is not found. Since, in many cases in which life is lost, the assisted unit is not found, no information on time is available in these cases to generate a survival curve. Of all the information in the SAR data base, however, the next best statistic is distance to scene which is used as a base for a survival curve.

MINITAB was used to generate histograms of sorties in which any lives were lost and sorties in which all lives were saved as a function of distance to scene. These data are grouped into two-nautical mile cells and the probability that a sortie will be involved in a case in which all lives are saved as a function of distance to scene computed. These probabilities are plotted and a regression line determined (see figure 2-6). The probability of .63 at 2 nautical miles is computed by dividing the total number of sorties of 2 nautical miles or less on which all lives were saved (292) by the total number of sorties of 2 nautical miles or less (168 on which one or more lives were lost plus the 292). Although the probability of saving lives is (1501-225)/1501 = .85 (see figure 2-16), these probabilities for individual sorties are much lower. Since many more sorties are generally dispatched on cases in which life is lost versus usually one sortie on cases in which all lives are saved, the probability that an individual sortie will be involved in a case in which all lives are saved is significantly less than .85. The data, which resemble a scatter plot, are not explained by a regression line.

Two possible explanations, however, help to shed light on the data. Some cells contain only one or two data points, sometimes resulting in a probability of 1.0 or 0.0 and are not representative of the probability of survival. If these small cells are combined with adjoining cells, the data support a definite trend. (Cells include a minimum of 15 lives lost.) Figure 2-7 plots the probability of survival using the larger cells for distances from 0 to 50 nautical miles and figure 2-8 for distances from 50 to 99+ nautical miles. It is clear from these graphs that the probability of survival is a

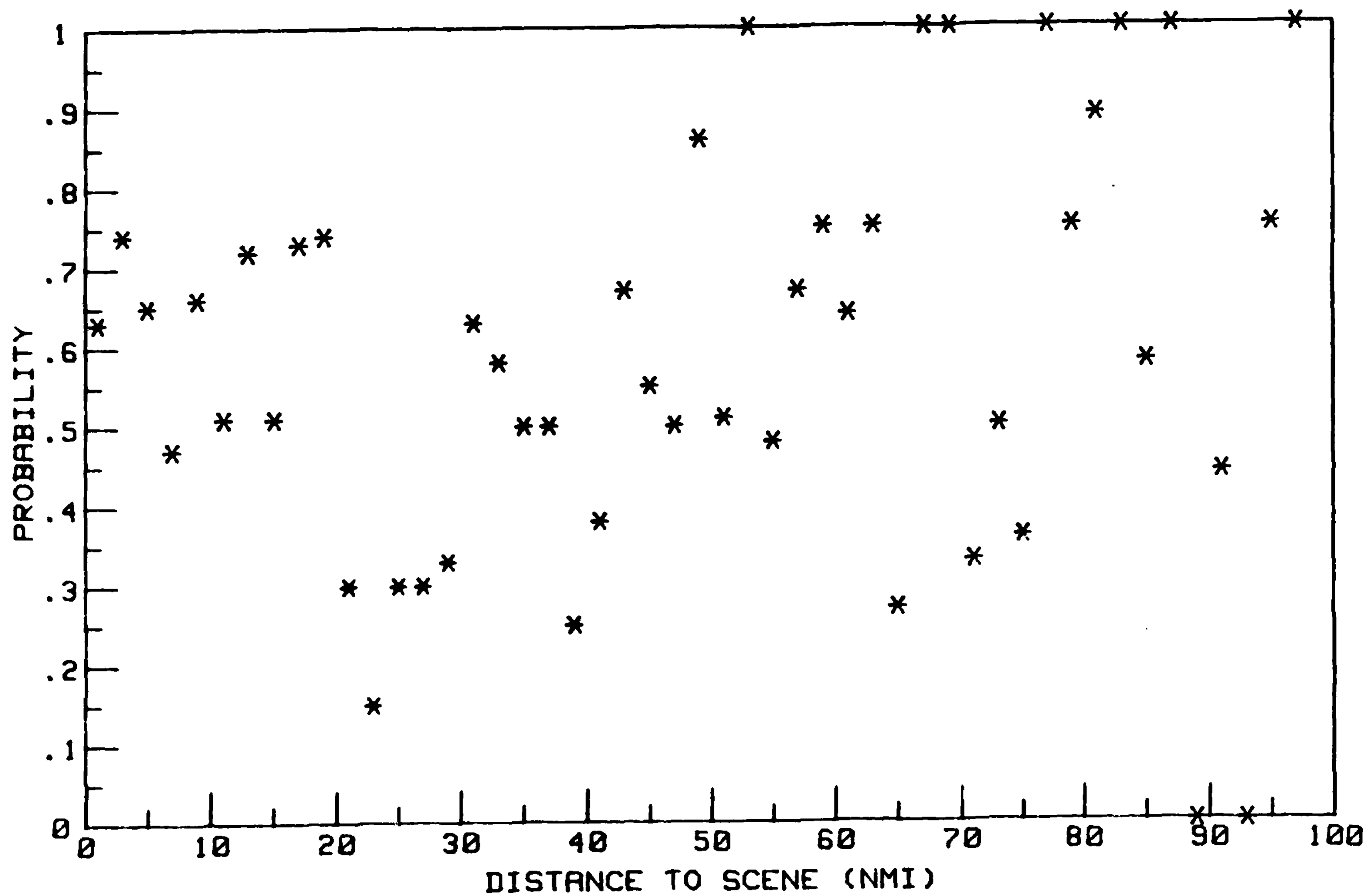


Figure 2-6. Probability that a Sortie Will Save All Lives on a Case (Scatter Plot)

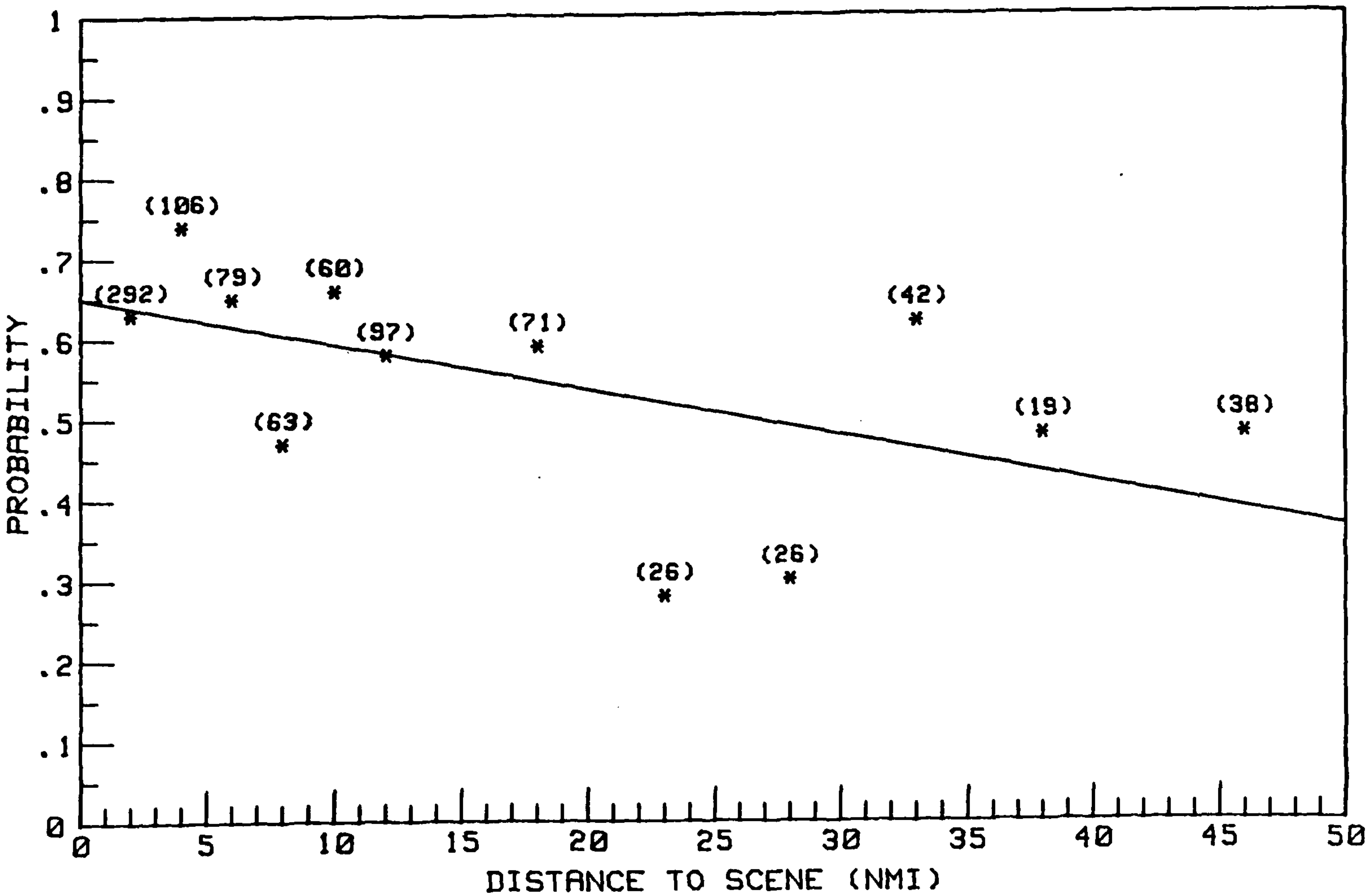
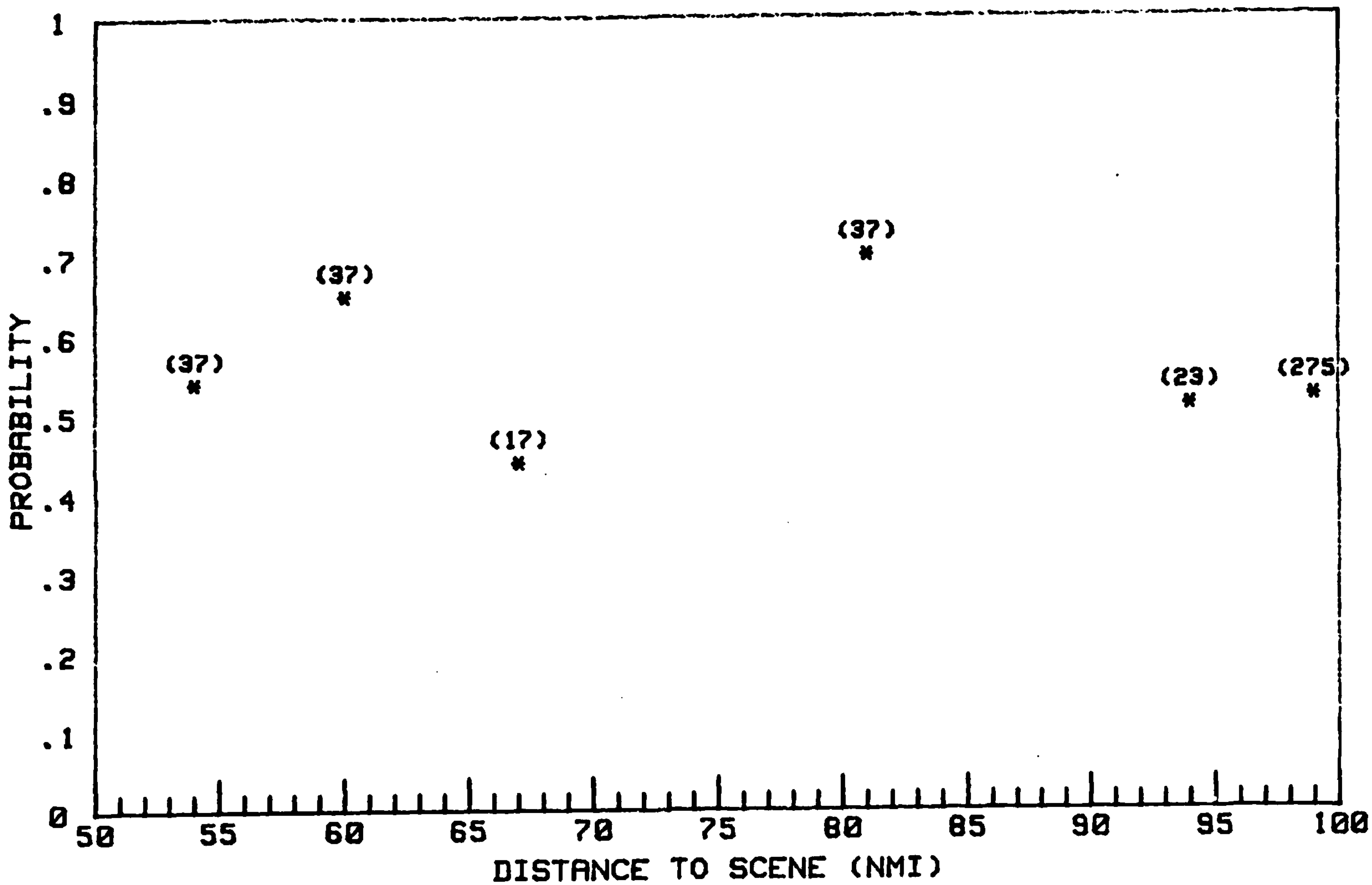


Figure 2-7. Probability that a Sortie Will Save All Lives on a Case (0 to 50 Nautical Miles)
(Numbers in parentheses are the numbers of sorties)



NOTE: The 275 cases occurred beyond 98 nautical miles.

Figure 2-8. Probability that a Sortie Will Save All Lives on a Case (50 to 99+ Nautical Miles) (Numbers in parentheses are the numbers of lives saved)

function of distance to scene (which can be equated with time) for sorties of 50 nautical miles or less. The stable probability of survival beyond 50 nautical miles is interesting. It may be due to any of a number of factors, including better safety equipment or crew skill on boats that travel farther from port, use of aircraft on longer range missions, or on other unknown factors. Aircraft accounted for 36 percent of the sorties of 50 nautical miles or less to scene, but accounted for 80 percent of the sorties from 50 to 100 nautical miles and 91 percent of the sorties beyond 100 nautical miles.

2.3.3 Environmental Factors

The hypothermia curve (see figure 2-9) demonstrates that survival in water is very much a function of time and water temperature. The probability of survival for a range of temperature and distance to scene factors is presented in figure 2-10. Only the lowest temperatures have any effect on the probability of survival. It must be noted, however, that cases with low probabilities of survival are samples with five or less

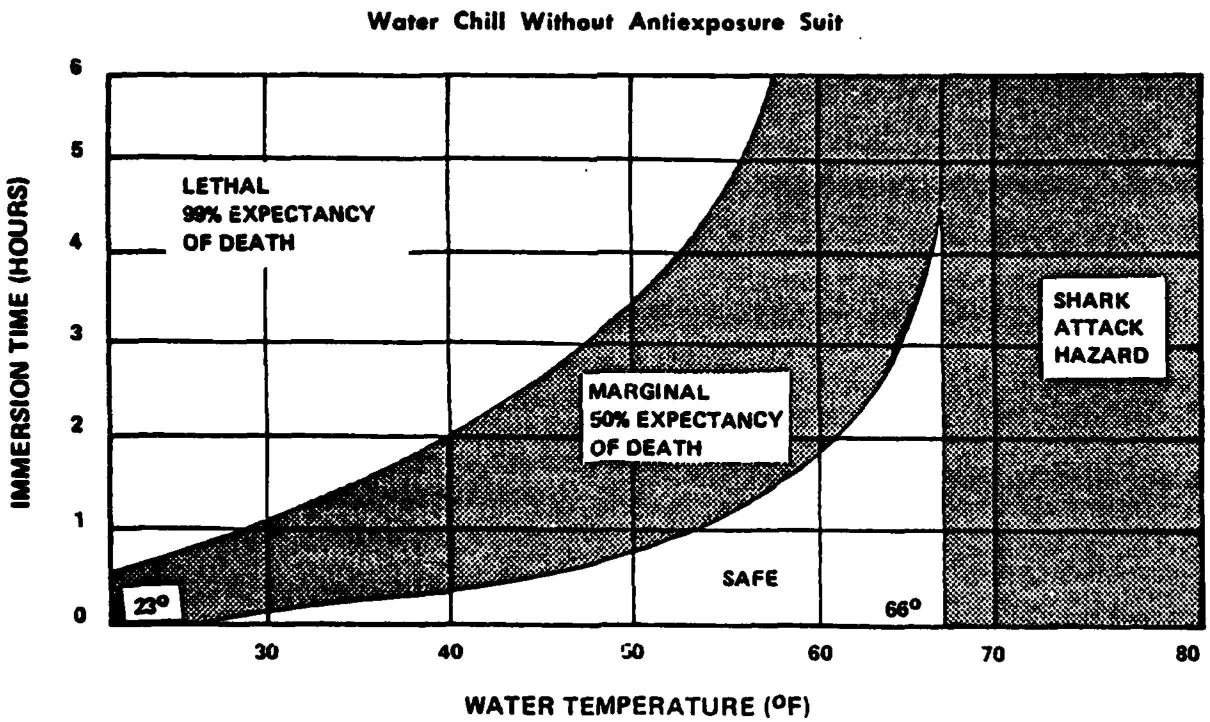


Figure 2-9. Hypothermia Curve (U.S. Coast Guard Search and Rescue Manual, amendment 6, page 7-9)

Temperature (degrees Celsius/Fahrenheit)

Distance to Scene (nmi)	0-14/32-57		14-18/57-64		18-22/64-72		22-26/72-79		26+/79+		All Temperature	
	p	#	p	#	p	#	p	#	p	#	p	#
0-10	.80	49	.88	168	.96	194	.95	148	.81	153	.89	712
11-20	.89	27	.84	64	.83	86	.73	15	.94	68	.86	260
21-30	.40	5	.79	24	.79	14	.75	4	.86	36	.80	83
31-40	.86	14	.92	13	.89	45	1	1	.85	13	.88	86
41-50	.67	3	.81	31	.90	21	.80	5	1	5	.85	65
51-60	.80	5	.78	23	.91	11	.83	6	1	9	.85	54
61-70	.50	2	.93	15	.73	22	1	2	.5	2	.79	43
71-80	.40	5	1	10	1	12	1	3	.67	6	.86	36
81-100	1	53	.91	103	.66	106	1	9	.96	97	.87	368
All Distances	.85	163	.87	451	.85	511	.92	193	.88	389	.87	1707

Note:

p = Probability of survival

= Number of sorties

There is no way to determine which people were actually in the water

Figure 2-10. Probability of Survival (Temperature and Distance Sensitivity)

cases. Contrary to common wisdom, it seems fair to conclude that water temperature is not a significant factor in probability of survival according to the SAR data base. (However, it needs to be emphasized that not all of the cold water SAR cases involved persons actually in the water). Sea state, wind speed, and visibility also do not significantly affect the probability of survival (see figures 2-11 and 2-12).

2.3.4 Use of AMV

The AMV will contribute to SAR mission effectiveness primarily in cases where its capability for high speed in the seaway will enable it to arrive on scene significantly earlier than conventional craft. Figure 2-13 is a modified boxplot describing the distance to scene distribution by district (the inland waterways and Hawaii are not included in this analysis). In the boxplot, the upper and lower quartiles of the data for each district are represented by a box and the median is marked with a "+". A confidence interval for the population median is put on each boxplot. The ends of the confidence interval are indicated by parentheses. Two groups whose intervals do not overlap are significantly different at roughly the 5-percent level. Tails showing outlyer values were removed from the boxplot for simplicity. Figure 2-14 is a boxplot of distance to scene with the C-130 aircraft sorties removed from the data and figure 2-15 is a boxplot with all aircraft removed.

The fifth, seventh, and seventeenth districts have significantly greater distances to scene distributions than the other districts. The case load in district seven is significantly greater than in any of the other districts. Figure 2-16 contains a breakdown of the case load used in this study. Both the workload and distance to scene distributions suggest that the AMV would contribute most significantly to SAR in the seventh district. Since the AMVs will most likely be stationed in the seventh district, for law enforcement patrols, they will be available to be diverted to SAR missions in the district where they will be of most use.

Wind (knots)

Observed Sea (feet)	1		5		7		10		15		25		35		50		All Wind	
	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#
0	.86	153	.93	67	.91	35	.79	43	.53	47	1	2	1	1	0	0	.82	348
1	.92	12	.84	50	.75	20	.96	53	.90	40	.86	7	0	0	0	0	.88	182
2	.91	11	.83	18	.92	37	.82	65	.79	47	1	73	0	0	0	0	.88	251
3	1	8	.82	17	.85	13	.86	43	.87	62	.80	25	1	3	0	0	.86	171
4	0	0	.83	6	.78	9	.90	30	.91	68	.90	40	1	1	1	9	.90	163
5	.89	9	0	0	1	6	.89	38	.85	34	.81	21	1	9	0	1	.87	118
6	1	5	1	13	0	1	.89	47	.91	22	.90	49	1	1	0	2	.89	140
8	1	6	1	7	0	0	.92	13	.97	63	.96	57	1	5	0	0	.97	151
11	0	0	0	1	1	3	.83	24	.80	5	.89	35	.98	40	1	7	.90	115
16	0	0	0	0	1	1	0	0	0	0	1	13	1	3	1	9	1	26
23	.31	35	0	0	0	0	0	0	1	4	1	8	0	4	1	1	.46	52
All Sea	.80	239	.88	179	.87	125	.87	356	.85	392	.92	330	.93	67	.90	29	.87	1717

Note:

p = Probability of survival

= Number of lives lost and lives saved

Figure 2-11. Lives Lost/Lives Saved (Sea State and Wind Speed Sensitivity)

Visibility (nmi)

Observed Sea (feet)	0		1		2		3		4		5		6		7		8		9		All Visibility	
	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#	p	#
0	.85	92	1	6	.86	7	0	0	1	1	.95	20	.83	6	1	23	.92	36	.74	157	.82	348
1	1	3	.92	12	.85	20	.67	6	.89	9	1	8	.91	11	.56	9	.97	33	.89	71	.88	182
2	.75	4	.80	5	.67	3	.83	6	.80	5	.92	25	.60	10	.97	62	.88	49	.88	82	.88	251
3	1	7	1	3	1	3	1	5	1	5	.88	17	.95	20	.71	7	.73	15	.83	89	.86	171
4	.93	28	.82	22	1	4	0	0	.92	13	.85	26	1	11	1	6	.83	6	91	47	.90	163
5	1	1	0	4	0	0	.33	3	1	10	.87	15	1	12	1	10	.71	17	.96	46	.87	118
6	20	5	1	4	0	0	1	5	1	8	.60	10	1	8	0	3	1	59	.89	38	.89	140
8	1	19	1	2	1	4	0	0	1	26	1	17	1	2	0	1	.96	47	.94	33	.97	151
11	1	38	1	19	.5	2	1	8	1	1	.88	8	1	1	.80	5	0	4	.86	29	.90	115
16	1	2	0	0	1	3	0	0	0	0	0	0	0	0	1	7	1	3	1	11	1	26
23	0	0	0	0	1	1	0	0	0	0	.40	40	0	0	1	4	1	1	.33	6	.46	52
All Sea	.89	199	.87	77	.87	47	.85	33	.96	78	.78	186	.91	81	.91	137	.90	270	.85	609	.87	1717

Note:

p = Probability of survival

= Number of lives lost and lives saved

This figure contains all cases in the analysis, whereas figure 2-4(a) contains only cases beyond 3 nautical miles from shore.

Figure 2-12. Lives Lost/Lives Saved (Sea State and Visibility Sensitivity)

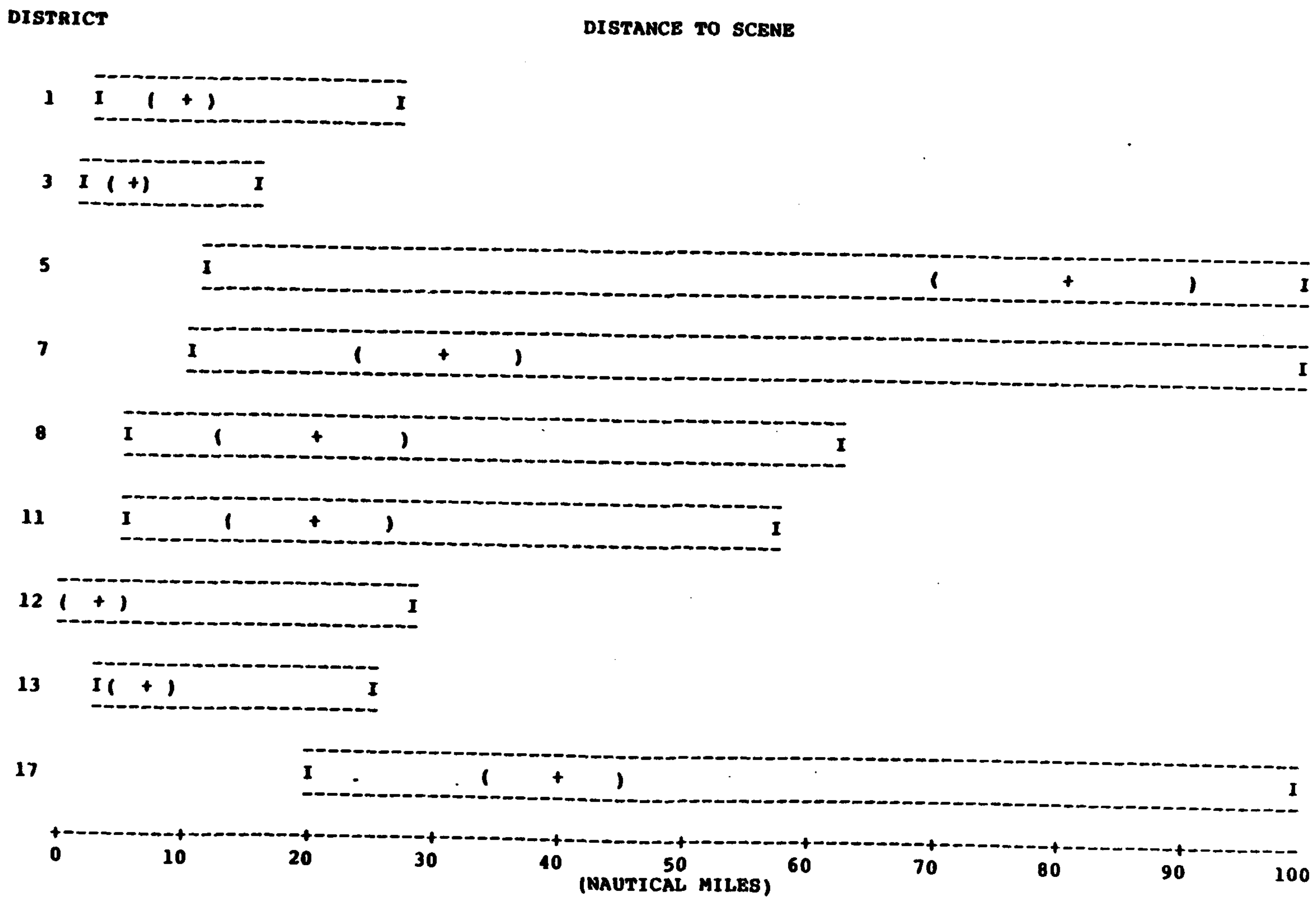


Figure 2-13. Distance to Scene by District (All Sorties)

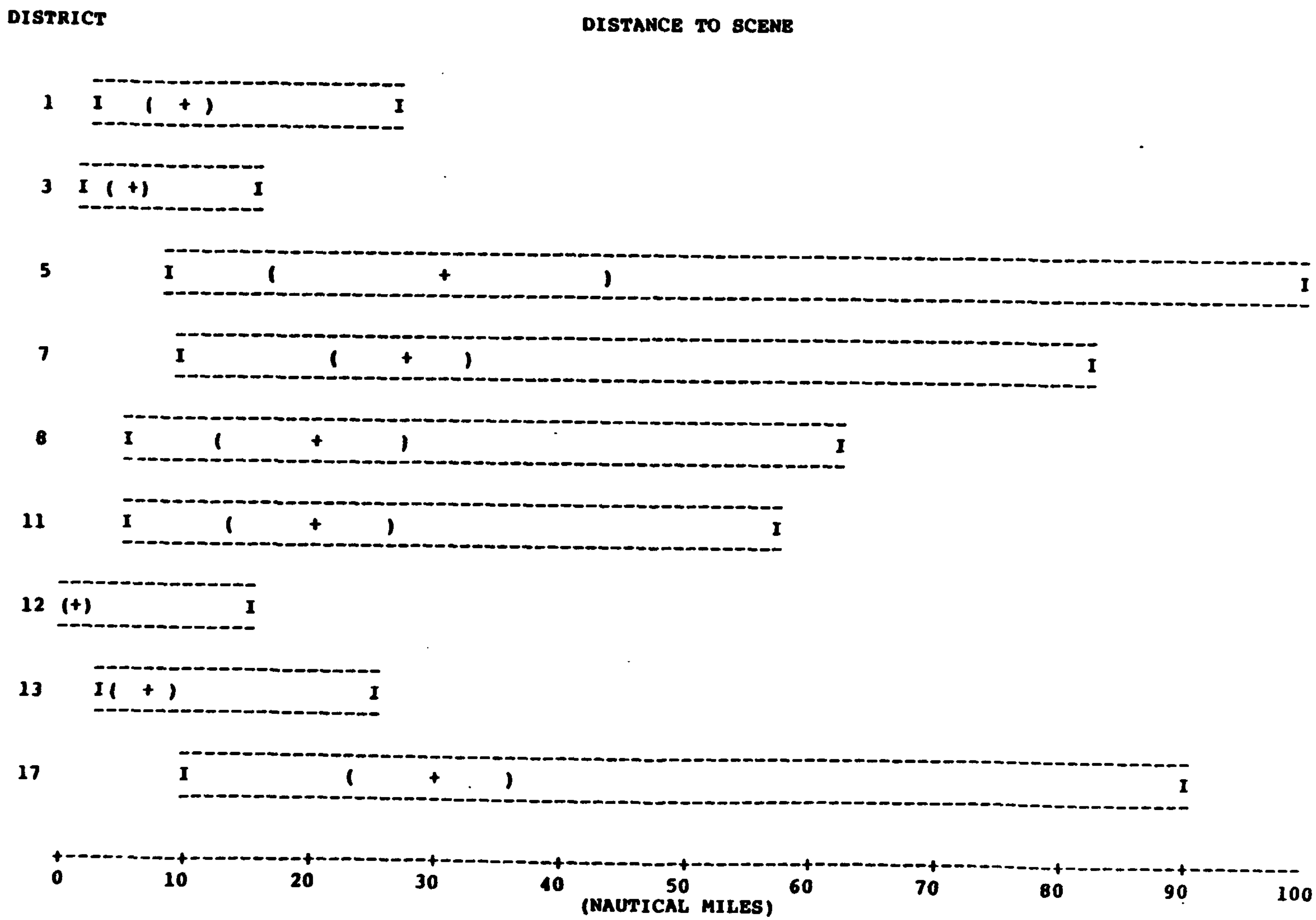


Figure 2-14. Distance to Scene by District (C-130 Aircraft Sorties Removed)

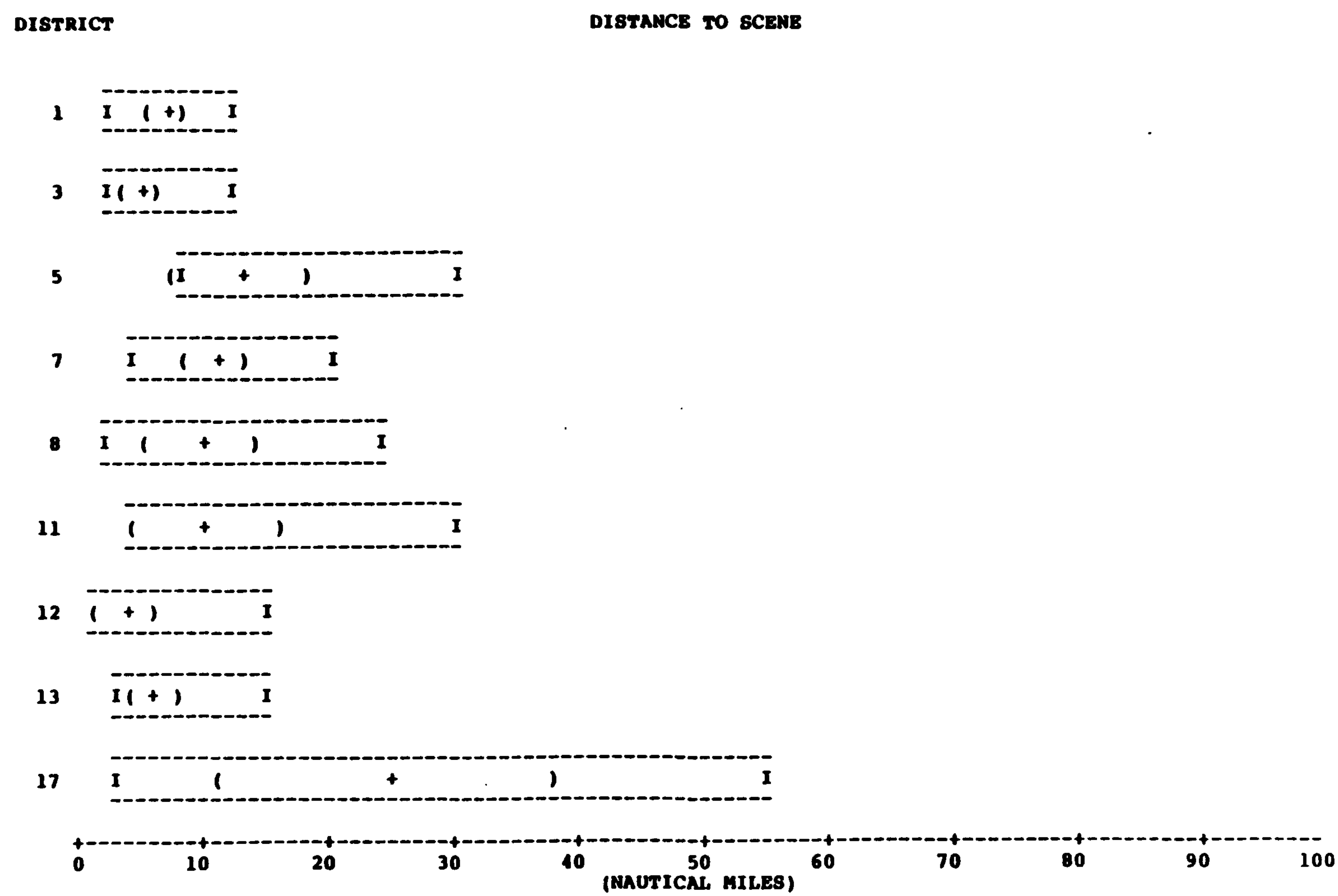


Figure 2-15. Distance to Scene by District (All Aircraft Sorties Removed)

ROWS: DISTRICT — COLUMNS: MONTH

DISTRICT		JAN	FEB	MAR	JULY	AUG	SEPT	ALL
1	LLB	0	0	0	1	10	0	11
	LLA	2	0	26	6	5	4	43
	LS	2	40	29	82	82	52	287
3	LLB	5	1	0	0	0	7	13
	LLA	8	0	1	8	6	5	28
	LS	2	2	1	87	60	58	210
5	LLB	0	0	0	2	0	0	2
	LLA	3	0	2	2	1	3	11
	LS	20	3	16	13	12	12	76
7	LLB	0	6	2	4	4	1	17
	LLA	3	10	10	9	24	4	60
	LS	21	57	88	41	103	96	406
8	LLB	0	7	1	4	3	1	16
	LLA	1	0	3	5	1	0	10
	LS	5	7	29	36	18	12	107
11	LLB	2	3	3	0	1	1	10
	LLA	2	2	2	2	3	5	16
	LS	19	15	11	23	41	20	129
12	LLB	0	1	0	2	1	0	4
	LLA	8	2	3	2	5	3	23
	LS	8	20	12	43	16	33	132
13	LLB	0	1	0	0	4	1	6
	LLA	1	3	2	4	10	3	23
	LS	7	5	7	35	37	15	106
17	LLB	0	0	29	1	3	1	34
	LLA	2	1	1	5	0	2	11
	LS	1	4	5	16	13	7	46
20	LLB	0	--	--	--	--	--	0
	LLA	0	--	--	--	--	--	0
	LS	1	--	--	--	--	--	1
21	LLB	--	--	--	--	0	--	0
	LLS	--	--	--	--	0	--	0
	LA	--	--	--	--	1	--	1
ALL	LLB	7	19	35	14	26	12	113
	LLA	30	18	50	43	55	29	225
	LS	86	153	198	376	383	305	1501

CELL CONTENTS --
LLB:LIVES LOST BEFORE COAST GUARD NOTIFIED
LLA:LIVES LOST AFTER COAST GUARD NOTIFIED
LS: LIVES SAVED

Figure 2-16. Case Load Distribution by District and Month

SECTION 3

CONCLUSIONS

While it is intuitively obvious that timely assistance is critical to saving lives in any rescue operation, it is difficult to quantify the potential contribution of craft speed in the seaway to SAR performance. The fact that the regression curve (see figure 2-7) has a Y intercept below .7 and a very gradual slope suggests either that 30 percent of the people who die after the Coast Guard is notified die very soon after notification before help can arrive, or that they are so severely injured or sick (e.g., heart attack) that saving life is not possible. It seems from the data that another 35 percent of the people could survive for a considerable additional time without assistance. Although the survival curve generated from the data does not follow the theoretical curve (figure 2-2) postulated at the beginning of the analysis, a definite time-dependent trend is identified for some cases.

In approximately one third of the SAR sorties, the probability of saving lives very definitely degrades with time. Consequently, a high-speed AMV could provide an increase in the probability of saving lives in cases where distance to scene is substantial. The relatively shallow slope of the curve suggests, however, that moderate speed advantages or speed advantages over short distances (especially if get-away time is increased for the AMV) will have little or no effect on SAR mission effectiveness.

To put the problem in perspective, however, it is necessary to identify the potential number of cases involved. Cases selected for analysis include all severe cases that occurred off the coast of the continental United States (including Alaska) during the winter months (January, February, and March) and the summer months (July, August, and September). This selection reduced the 1981 SAR data base to a subset that includes 776 cases and 2,392 rescue sorites. In these cases, 225 persons died, 77 within 10 nautical miles of help and 52 beyond 100 miles, leaving less than 100 cases within a range where the AMV speed in the seaway might have contributed to SAR performance. It is assumed that the initial response to cases beyond 100 nautical miles will be by aircraft. If, at most, one third of the deaths are sensitive to craft time in the seaway (one third die very quickly and the last third survive for a long time), the AMVs available when needed could affect, at most, 30 lives per year during the winter and summer months. Since the data selected for the analysis included only 6 months, it

could be postulated that 60 lives could be affected by an AMV in the course of a year. Assuming a liberal upper limit availability of 50 percent, the AMV could participate in 30 rescues per year on which life was lost that might have been saved. If the AMV is twice as fast as conventional craft, it could reduce by 50 percent the time required to arrive on scene. Since the survival curve in figure 2-7 is a straight line, the AMV (twice as fast as conventional craft) should be able to save an additional 15 lives per year, given 50 percent availability.

Placing a meaningful confidence interval on the survival curve is extremely difficult since the variances in the problem are so great. Variability in survival gear, hunger and thirst, physical condition of the victim, and psychological factors, as well as uncertainty as to the time the victim's life became in grave danger make the variance on the probability of survival (as a function of time after Coast Guard is notified) very great. The data on the SAR cases indicate that under identical environmental conditions the probability that an individual will survive t hours varies from 0.0 to 1.0 for a wide range of t.

SECTION 4

RECOMMENDATIONS

A number of recommendations are suggested by the analysis work used to prepare this report. The first set of recommendations pertains to the AMV analysis itself and the second set of recommendations to the SAR data base.

4.1 RECOMMENDATIONS - AMV ANALYSIS

The constant probability of survival beyond 50 nautical miles is interesting and, at this time, unexplained. A detailed analysis of this change in the survival curve should be performed to identify factors that might improve the probability of survival. Another area that requires more analysis is the relationship between aircraft and ships in SAR missions. If aircraft drop survival gear that enables people to survive until a boat arrives to rescue them, it is important to quantify the individual contribution both of the aircraft and of the boat. If the AMV is to be used in a SAR role, it is important to determine the extent to which it can replace aircraft without reducing the probability of survival.

Because of the small sample sizes that result when SAR cases are divided into environmentally significant categories, the analysis should be repeated using five years of data. These data would provide large samples that would be adequate for statistical analysis and would enable more accurate testing of the sensitivity of SAR MOEs to environmental factors.

4.2 RECOMMENDATIONS - SAR DATA BASE

4.2.1 Present Data Base

The extensive data base developed by the Coast Guard over the years contains valuable information on SAR performance. The SAR data base does, however, require extensive editing before it can be used for statistical/operations analysis. Although a few errors in 93,000 records are statistically insignificant, misleading statistics can be

generated if large errors occur in a few records of a subset of the data base that is of interest. Consequently, it is necessary to identify highly suspect data and either correct the data, if possible, or flag the data so that it is not included in statistical computations. Several recommendations are made:

1. The types of errors that occur in the SAR data base should be identified. This task involves identifying absolute errors such as negative elapsed times and also probable errors such as the involvement of a Great Lakes asset at latitude/longitude coordinates in the South Pacific.

2. The Coast Guard edit program should be enhanced to flag more errors than it presently does.

3. Clearly erroneous data that cannot be corrected after the standard number of attempts should be entered into the SAR data base with an error code.

4. Algorithms should be written and made available to analysts that would flag erroneous and highly suspect entries in the data base. Suspect data are neither all correct nor all incorrect. Since a decision must be made about including suspect data in computations, suspect data must be identifiable.

4.2.2 Restructure of SAR Data Base

Two serious problems must be addressed in regard to the SAR data base: one is the number of seemingly uninformative entries, and the second is the inaccuracy of some of the information. These two problems may be interrelated in that the requirements for completing the entire SAR form for thousands of towing cases may make personnel less sensitive than desired to the importance of accurate information in true search and rescue cases. A number of recommendations are made:

1. Separate true life threatening/life critical search and rescue from the AAA type of towing, breakdown, and refueling services.

2. Identify the information needed in each type of case. Separate forms, or a subset of the SAR form, should be used for AAA-type services.

3. Eliminate data elements that cannot be collected with adequate accuracy. It is imperative that information in the data base be accurate and informative. If a type of information cannot be collected accurately, it is not helpful to have this information in the data base. Entries would be better left blank than completed with guess work. It is understandable that the requirement of performing a SAR mission and saving lives overrides completing forms. If accurate information (e.g., wind speed) cannot be collected during the mission, it should be coded as "unavailable".

4. Eliminate data that does not shed light on SAR missions. If, for instance, personnel and craft always perform adequately, this information is not needed in the SAR data base.

5. Investigate methods to obtain information electronically by interface to ship equipment. This would reduce the work load on the crew and probably provide more accurate information. With elements of the SAR record that could be obtained electronically, the crew's responsibility would be reduced to verifying or correcting these data.

These recommendations will significantly reduce the size of the SAR data base without sacrificing any useful information. They would also reduce the workload of collecting and editing the SAR records and significantly reduce the time and cost of using the SAR data base. Moreover, these recommendations will improve the accuracy of the information contained in the data base. This improved accuracy is essential if the SAR data base is to be used for operations analysis.

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a. U. S. Navy Marine Climatic Atlas of the World, Volume I and Volume 2, (Revised 1974), Naval Weather Service Detachment, Asheville, NC.

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